

Avatars in Educational Virtual Reality: A Systematic Review

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Abstract—Avatars are users' digital representations in a virtual reality (VR) environment. As a core medium in VR, avatars may do more than merely represent users; they can actively transform learners' perceptions, experiences, and learning effectiveness. To explore the current research progress in this domain, this systematic review synthesizes existing studies on avatar use in educational VR, focusing on application contexts, learning effects, underlying mechanisms, theoretical foundations, and design considerations. Data were sourced from three databases: Web of Science, IEEE Xplore, and Google Scholar. Following a rigorous screening process, 15 articles were included for analysis. The results indicate that avatars have been widely adopted across diverse educational contexts, including teacher training, language learning and medical education. They influence learning outcomes through three core mechanisms: cognitive, affective-motivational, and social interaction pathways. The reviewed studies are predominantly grounded in theories including embodied cognition, social presence, the illusion of body ownership, and the Proteus effect. Moreover, existing research particularly focuses on avatar visual presentation, interactive functionality, and socio-psychological aspects. This review provides a structured synthesis of existing evidence and offers a systematic reference to inform future design of avatars in VR-based education.

Keywords—Avatar, Virtual Reality (VR), Education, Systematic Review

I. INTRODUCTION

Virtual reality (VR) has become an increasingly important medium for delivering immersive learning experiences [1]. Within VR environments, avatars function as users' digital representations [2], serving as an interface that connects learners with the virtual world, enables interaction, and supports the development of social presence [3]. It should be noted that some

conference papers and prior studies use the term avatar in a broad sense to refer to any virtual entity embodied in a virtual environment, including those driven autonomously by computer programs. However, in a stricter conceptual sense, avatars and agents differ in terms of control mechanisms. Avatars are virtual entities directly controlled by human users in real time, representing the users themselves. By contrast, agents are autonomous virtual entities whose behaviors are driven by computational rules or artificial intelligence models rather than direct human control [4]. In this study, we adopt this control-based definition to differentiate avatars from agents for conceptual clarity.

Accumulating evidence suggests that avatars can assume multiple roles like teachers and peers. They have been widely implemented across educational contexts such as medical education, teacher training, and language learning [5], where they significantly influence learners' cognitive, motivational, and social experiences [6]. Although a growing body of empirical research has examined the effects of avatar appearance and behavior [7], the literature still lacks a systematic synthesis integrating application scenarios, learning effects, underlying mechanisms, theoretical foundations, and design considerations. Therefore, this review aims to address the following four questions: (1) What application scenarios and learning effects of virtual avatars have been examined in VR-based education? (2) Through which mechanisms do avatars influence educational outcomes? (3) What core theoretical frameworks underpin such research? (4) Which aspects of avatar design do existing studies focus on?

II. METHOD

This study follows a systematic search strategy with predefined inclusion and exclusion criteria, adhering to PRISMA guidelines for methodological rigor [8][9].

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A. Search Strategy

Three databases were selected for the literature search: Web of Science, IEEE Xplore, and Google Scholar. The search period covered the last decade and was set from January 2015 to November 2025. The search query combined the terms “Avatar and Education and Virtual Reality”. Exclusion criteria included: non-English articles, non-journal or non-conference articles, review papers, articles irrelevant to the topic, and articles published outside the 2015-2025 period.

B. Selection of Studies

Initially, 134 articles were identified from the selected databases. After removing 7 duplicate records, 127 unique articles remained. Following the PRISMA methodology, a two-stage screening process was conducted. The first stage involved screening based on titles and abstracts to exclude articles evidently irrelevant to the research topic. In the second stage, the remaining articles underwent full-text review to further exclude those not meeting the inclusion criteria. After two rounds of screening, 15 articles were included. Figure 1 illustrates the selection process.

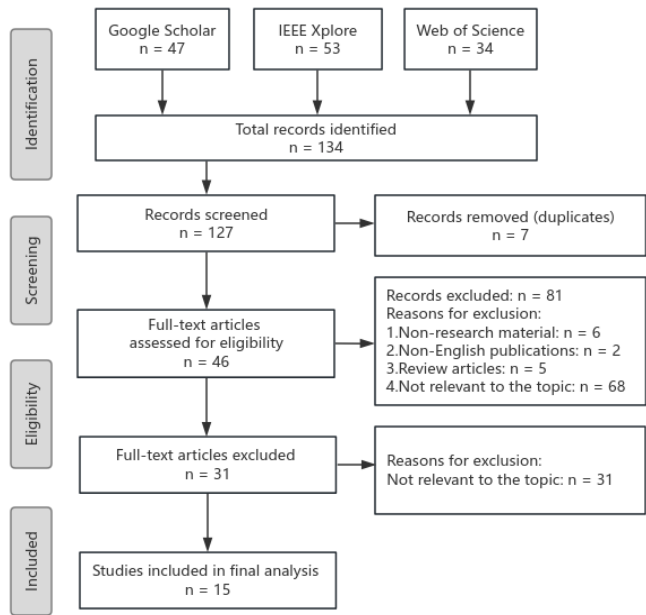


Fig. 1. Flow chart of the study selection process.

C. Data Analysis

To address the research questions, this study adopted a qualitative thematic analysis approach. All included articles were subjected to an in-depth examination, during which relevant findings were coded, compared, and synthesized to identify recurring themes and patterns.

III. RESULT

A. Application Scenarios and Effects

By analyzing the included papers, we identified four main scenarios where avatars are used in education.

1) Language Learning

In language learning, avatar applications primarily emerge in two scenarios. (1) As embodied extensions to promote experiential vocabulary memory. Fukushima et al. found that when learners actively controlled non-human avatars (e.g., a dragon) to perform embodiment actions in immersive VR, their long-term forgetting rates of English vocabulary significantly decreased compared to traditional flashcard methods [10]. Moreover, the retention strength of episodic memory positively correlates with vocabulary test scores, indicating that learner-driven avatars effectively enhance vocabulary acquisition. (2) As creative media supporting role-playing and script writing. Chien demonstrated that learners using 3D avatars for role-playing and creation reduced appearance anxiety, increased willingness and engagement in oral practice, and deepened understanding of language structures [11].

2) Teacher Training

In teacher training, avatars are mainly applied in two scenarios: (1) Relational competence training: Lindberg found that simulating interactions with avatar students of diverse personalities improved teachers’ emotional recognition and communication skills [12]. (2) Classroom discussion and thinking stimulation training: Using avatars to simulate classroom discussion practices enhanced teachers’ listening, questioning, and idea-connecting skills, promoted dialogue depth and inclusivity. Ultimately, it enhanced the teachers’ teaching confidence and their instructional competence [13].

3) Medical Education

Junga et al. compared two self-avatar designs and found that abstract green semi-transparent hands enabled faster task navigation and lowered entry barriers for novice learners, whereas realistic user-controlled hands significantly increased glove-wearing compliance during simulations [14]. These findings suggest that avatar realism differentially supports operational efficiency and the internalization of clinical behavioral norms, thereby shaping procedural adherence in VR medical training.

4) STEM Education

In programming learning, students utilized gender-matched and body-synchronized self-avatars within a VR environment to engage in programming through dance-based interactions. This embodied learning approach led to marked improvements in memory retention, conceptual understanding and multiple cognition, while also boosting task performance and fostering greater interest and confidence in computer science [15].

TABLE I. AVATAR APPLICATIONS IN EDUCATION

Avatar Role	Medical Education	Language Learning	Teacher Training	STEM Education
Body Extension		[10]		
Creative Medium		[11]		
Simulated Students			[12][13]	
Virtual Hand	[14]			
Self-Avatar				[15]

B. Underlying Mechanisms

Based on an in-depth analysis of the literature, this review identifies three core mechanisms through which avatars influence learning effectiveness, revealing how avatars affect learners' internal states and processes to ultimately impact learning outcomes.

1) Cognitive Mechanisms

The analysis indicates that avatars influence retention and transfer by altering embodied cognition and cognitive load. On the one hand, avatars can strengthen embodied cognition, thereby deepening conceptual understanding and supporting knowledge transfer. For example, in programming learning, gender-matched self-avatars improved learners' conceptual understanding and task quality, particularly at the remembering and understanding levels of Bloom's taxonomy [15]. In immersive sign language learning, switching among diverse self-avatars enabled engagement with multiple contextual environments, facilitating transfer to authentic situations and enhancing long-term retention [16]. On the other hand, avatars may also introduce extraneous cognitive load. According to the Cognitive Affective Model of Immersive Learning (CAMIL), avatar-induced presence and immersion can indirectly influence cognitive load levels [17]. When avatar-related cues exceed learners' processing capacity, they may function as additional cognitive demands rather than instructional support. Conversely, in cognitive tasks, the absence of self-avatars or gesture-based support restricts learners' ability to offload mental effort through embodied interaction, leading to increased cognitive load and impaired task performance [18].

2) Affective-Motivational Mechanisms

Avatars influence learning outcomes through multiple affective-motivational pathways, including enhancing motivation and interest, self-efficacy, and presence and immersion. Within the CAMIL framework, presence is conceptualized as a central psychological mechanism through which avatar-based environments foster intrinsic motivation, learning interest, and self-efficacy [17]. Empirical evidence supports this mechanism. Chien demonstrated that the use of 3D avatars in project-based comedy workshops significantly enhanced learners' sense of presence and boosted their motivation by reducing appearance-related anxiety and creating an enjoyable, immersive role-play context [11]. Pre-service special education teachers reported significantly higher self-efficacy after successfully managing instructional challenges through interactions with avatar students in simulated virtual classrooms [12].

3) Social Interaction Mechanisms

Avatars enhance learning effectiveness in VR environments by facilitating collaborative interaction and social presence.

For example, avatars promote active peer and learner-environment interaction. In foreign language courses, learners engaged in avatar-mediated role-play dialogues to collaboratively complete scriptwriting and performances, which improved language expression and teamwork skills [11]. In teacher training, avatars simulated students' responses during classroom discussions, enabling pre-service teachers to

dynamically adjust questioning strategies and refine instructional skills through real-time interaction [13]. Falloon et al. demonstrated that avatars, by providing visible personas and immersive interactive environments, can enhance student engagement, foster collaboration, and support the development of higher order thinking skills [19].

Furthermore, avatars contribute to the formation of social presence. Lindberg's study demonstrated that pre-service teachers, when interacting with avatar students exhibiting distinct personality traits, attended to non-verbal cues and adjusted their communication strategies accordingly, suggesting that avatars can effectively elicit a strong sense of social presence [12].

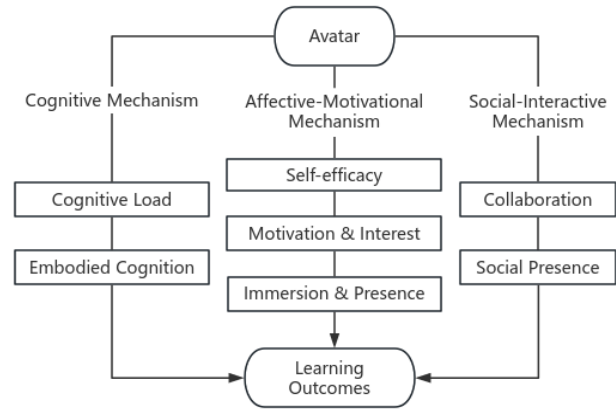


Fig. 2. Mechanistic Framework of Avatar Effects on Learning Outcomes

C. Core Theories

1) Embodied Cognition Theory

Embodied cognition posits that cognitive processes are deeply dependent on the physical characteristics of an agent's body. This means that bodily features external to the brain (such as perceptual systems, motor systems, bodily form, and ways of interacting with the environment) play significant causal or constitutive roles in cognitive processing. Cognition does not occur solely in the brain but is the product of the dynamic coupling of brain, body, and environment [20]. This theory provides a crucial analytical framework for understanding how users learn and construct meaning through digital avatars as proxy bodies [21].

2) Social Presence Theory

Social presence theory suggests that a medium's capacity to convey social cues directly affects users' perception of each other's presence [22]. In educational technology, this perception has been confirmed as a key factor predicting online learner satisfaction and engagement [23]. As media evolve towards VR, the theory has been refined into a multidimensional framework encompassing "co-presence," "psychological involvement," and "behavioral engagement," providing nuanced analytical tools for assessing users' social experiences in immersive environments [24]. Therefore, social presence is a core theoretical lens for examining whether virtual avatars can serve as effective social partners to facilitate instructional interaction.

3) Illusion of Body Ownership

The illusion of body ownership is a key theory for understanding user acceptance of virtual avatars. The classic "rubber hand illusion" experiment demonstrated that when synchronous tactile-visual stimulation is applied to a hidden real hand and a visible rubber hand, individuals perceive the external object as part of their own body [25]. This mechanism based on multisensory integration extends into VR: when users see a virtual body synchronized in real-time with their own movements through a headset, they experience a strong sense of body transfer, feeling that the virtual avatar belongs to them [26]. This theory provides the fundamental principle for designing VR educational avatars that effectively establish user body ownership.

4) Proteus Effect Theory

The Proteus Effect posits that the characteristics of a user's virtual avatar can influence their behavior and attitudes [27]. Research indicates that individuals tend to adapt their behavior and self-perception to align with the traits of their avatar. For example, embodying an attractive avatar can boost users' confidence and promote greater engagement and task performance in learning contexts [28]. This theory offers an important lens for understanding how avatars shape motivation and behavioral change in educational VR settings.

D. Avatar Design

Current avatar design primarily focuses on three aspects: visual presentation, interactive functionality, and socio-psychological considerations.

In visual presentation, the dragon avatar's non-human appearance was designed with features like wings and a tail, enhanced by dynamic bones and inverse kinematics to create natural movement. This visually coherent design aimed to strengthen immersion in the learning environment [10]. Junga et al. found that realistic hand representation significantly increased users' glove usage in VR medical training, indicating that visual realism helps reinforce training of hand-related medical behaviors [14].

In the interactive functionality dimension, avatars should support natural, consistent interaction and action mapping. In immersive VR, users control a "dragon" avatar with unique gestures and movements. By performing physical activities that are semantically aligned with vocabulary, strong episodic memory traces are established, making the learning process efficient and engaging [10]. Effective VR interaction design enables learning through congruent hand gestures and controls. Gestures well-mapped to the content enhance learner agency, ownership, and knowledge retention [29].

In socio-psychological aspects, encouraging the creation of authentic self-representational avatars helps maintain academic performance and self-efficacy, avoiding potential anxiety triggered by idealized or future-self designs [30]. Additionally, matching avatar gender characteristics with learners can enhance social identity, foster social connection, and thereby improve learning outcomes [31].

IV. DISCUSSION

A. What are the Application Scenarios and Effects of Virtual Avatars in VR Education?

In VR education, avatars play different roles and are applied to various educational scenarios to produce corresponding learning effects. In language education, avatars as body extensions and creative media effectively promote oral presence, experiential vocabulary learning, and language application skills [10][11]. In teacher training, avatars enhance teacher relational competence, instructional skills, and self-efficacy through simulated teacher-student interaction [12][13]. In medical education, by serving as interactive media, avatars enhance procedural efficiency, offer real-time feedback and instructional support, and thereby improve learners' clinical skills and knowledge retention [14]. In STEM education, avatars enhance learning engagement, cognitive understanding, and skill performance by providing embodied, immersive experiences that increase student confidence and interest [15]. In summary, avatars promote skill internalization, knowledge retention, and emotional identification through creating low-risk, highly immersive simulated scenarios with embodied interaction and immediate feedback.

B. What are the Underlying Mechanisms through which Avatars Produce Effects in VR Education?

Virtual avatars primarily influence learning outcomes through three interrelated mechanisms: cognitive, affective-motivational, and social interaction. Cognitively, avatars promote knowledge understanding and memory retention by enhancing embodied cognition and providing immediate visual feedback [15][16]. However, poor avatar design can increase learners' cognitive load and inhibit learning effectiveness [17][18]. In terms of affect and motivation, well-designed avatars enhance environmental realism and appeal, thereby stimulating intrinsic motivation, interest, and self-efficacy, providing a positive psychological foundation for learning [11][12][17]. Socially, avatars serve as interaction media that promote collaboration, dialogue, and knowledge co-construction, while enhancing social presence to improve learning outcomes [11][13][19]. In conclusion, understanding these mechanisms is crucial, and future research should focus on their interaction effects across different educational contexts.

C. What are the Core Theories Related to Avatars?

Most avatar-related research focuses on four core theories: embodied cognition, social presence, the illusion of body ownership and the Proteus effect. Embodied cognition theory posits that cognition depends on body-environment interaction, with avatars as proxy bodies promoting knowledge construction through embodied action [20][21]. Social presence theory emphasizes that avatars convey social cues that foster a sense of presence, which is crucial for promoting instructional interaction and emotional engagement [22][23][24]. The illusion of body ownership theory explains at the perceptual level how users come to identify with a virtual body as their own through multisensory synchronization, forming the foundation for other effects [25] [26]. Proteus effect further reveals that avatar characteristics shape user behavior and self-perception, providing a motivational and behavioral lens for understanding avatar-based learning [27] [28]. These four theories

systematically elucidate the mechanisms of avatars in VR education from cognitive, social, perceptual, and behavioral perspectives.

D. Which Aspects of Avatar Design do Existing Studies Focus on?

Existing avatar design research focuses on three main aspects. In visual presentation, avatar visual design should adhere to the principle of visual consistency to enhance immersion [10], while it should balance realism and interaction cues to enhance embodied cognition and behavioral training effectiveness [14]. In interactive functionality, ensure that the avatar's gestures and movements are semantically clear and closely aligned with the learning content to enhance the learner's sense of embodiment, episodic memory and memory retention [10][29]. Regarding socio-psychological aspects, avatars representing authentic self help maintain self-efficacy [30]. Furthermore, customizing avatars to match learners' social attributes such as gender can strengthen the avatar-self connection and influences their motivation and behavior [31]. Taken together, effective avatar design should follow an integrated principle of visual guidance, interaction reinforcement, and psychological matching to synergistically improve VR learning outcomes.

V. CONCLUSION

This study conducted an in-depth analysis of 15 included articles, systematically reviewing the progress of research on virtual avatars in VR education. The findings reveal that virtual avatars are widely used in scenarios such as medical education, language learning, and teacher training, primarily influencing learning outcomes through cognitive, affective-motivational, and social interaction mechanisms. Their theoretical foundations include embodied cognition, social presence, the illusion of body ownership and the Proteus effect. Existing research predominantly focuses on design dimensions such as visual presentation, interactive functionality, and socio-psychological aspects, yet theoretical integration and investigation of mechanism interactions require further deepening. Future avatar research should strengthen contextualized design, better integrate theory with empirical evidence, and explore intelligent technologies enabled by new advancements to drive VR education towards more efficient and immersive development.

REFERENCES

- [1] J. Radianti, T. A. Majchrzak, J. Fromm, and I. Wohlgenannt, "A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda," *Comput. Educ.*, vol. 147, p. 103778, 2020. <https://doi.org/10.1016/j.compedu.2019.103778>
- [2] K. L. Nowak and J. Fox, "Avatars and computer-mediated communication: A review of the definitions, uses, and effects of digital representations," *Rev. Commun. Res.*, vol. 6, pp. 30–53, 2018. <https://doi.org/10.12840/issn.2255-4165.2018.06.01.015>
- [3] B. E. Mennecke, J. L. Triplett, L. M. Hassall, Z. Jordán Conde, and R. Heer, "An examination of a theory of embodied social presence in virtual worlds," *Decision Sciences*, vol. 42, no. 2, pp. 413–450, May. 2011.
- [4] Nowak, K. L., & Biocca, F. "The effect of the agency and anthropomorphism on users' sense of telepresence, copresence, and social presence in virtual environments," *Presence: Teleoperators and Virtual Environments*, vol. 12, no. 5, pp. 481–494, Oct. 2003.
- [5] J. Fox and J. N. Bailenson, "Virtual self-modeling: The effects of vicarious reinforcement and identification on exercise behaviors," *Media Psychology*, vol. 12, no. 1, pp. 1–25, 2009.
- [6] B. Dalgarno and M. J. W. Lee, "What are the learning affordances of 3-D virtual environments?," *Br. J. Educ. Technol.*, vol. 41, no. 1, pp. 10–32, Jan. 2010. doi: 10.1111/j.1467-8535.2009.01038.x.
- [7] J. Fox et al., "Avatars versus agents: A meta-analysis quantifying the effect of agency on social influence," *Hum.-Comput. Interact.*, vol. 30, no. 5, pp. 401–432, 2015. <https://doi.org/10.1080/07370024.2014.921494>
- [8] M. Montenegro-Rueda, J. Fernández-Cerero, J. M. Fernández-Batanero, and E. López-Meneses, "Impact of the implementation of ChatGPT in Education: A Systematic Review," *Computers*, vol. 12, no. 8, p. 153, Aug. 2023. doi: 10.3390/computers12080153.
- [9] M. J. Page et al., "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews," *J. Clin. Epidemiol.*, vol. 134, pp. 178–189, Jun. 2021. doi: 10.1016/j.jclinepi.2021.03.001.
- [10] S. Fukushima, K. Sakamoto, and Y. Nakamura, "NariTan: Enhancing Second Language Vocabulary Learning Through Non-Human Avatar Embodiment in Immersive Virtual Reality," *Multimodal Technol. Interact.*, vol. 8, no. 10, p. 93, 2024.
- [11] P. -L. Chien, "Utilizing 3D Avatars in Virtual Spaces for Foreign Language Education: A Case Study on Role-Play Conversation Practice through Project-Based Comedy Workshops in Japanese Classes," 2025 13th International Conference on Information and Education Technology (ICIET), Fukuyama, Japan, 2025, pp. 197–203, doi: 10.1109/ICIET66371.2025.11046288.
- [12] S. Lindberg, "Using virtual simulations with avatars to train pre-service special needs teachers' relational competence: possibilities and limitations," *Cogent Educ.*, vol. 12, no. 1, p. 2457290, 2025.
- [13] S. M. Moody and C. Finkelstein, "Using avatar rehearsals to practice eliciting student thinking with preservice teachers," *J. Res. Technol. Educ.*, vol. 57, no. 6, pp. 1258–1275, 2025.
- [14] A. Junga et al., "Rethinking interaction design-special implications for interaction concepts in medical education using virtual reality," *Virtual Real.*, vol. 29, no. 3, p. 98, 2025.
- [15] D. Parmar et al., "How Immersion and Self-Avatars in VR Affect Learning Programming and Computational Thinking in Middle School Education," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 29, no. 8, pp. 3698–3713, 1 Aug. 2023, doi: 10.1109/TVCG.2022.3169426.
- [16] T. Mizuho, S. Takenaka, T. Narumi and H. Kuzuoka, "Multiple Self-Avatar Effect: Effects of Using Diverse Self-Avatars on Memory Acquisition and Retention of Sign-Language Gestures," in *IEEE Transactions on Visualization and Computer Graphics*, vol. 31, no. 9, pp. 5116–5129, Sept. 2025, doi: 10.1109/TVCG.2024.3433498.
- [17] G. Makransky and G. B. Petersen, "The cognitive affective model of immersive learning (CAMIL): A theoretical research-based model of learning in immersive virtual reality," *Educ. Psychol. Rev.*, vol. 33, no. 3, pp. 937–958, 2021.
- [18] A. Steed, Y. Pan, F. Zisch and W. Steptoe, "The impact of a self-avatar on cognitive load in immersive virtual reality," 2016 IEEE Virtual Reality (VR), Greenville, SC, USA, 2016, pp. 67–76, doi: 10.1109/VR.2016.7504689.
- [19] G. Falloon, "Using avatars and virtual environments in learning: What do they have to offer?," *Brit. J. Educ. Technol.*, vol. 41, no. 1, pp. 108–122, 2010.
- [20] M. Wilson, "Six views of embodied cognition," *Psychon. Bull. Rev.*, vol. 9, pp. 625–636, 2002. <https://doi.org/10.3758/BF03196322>
- [21] K. Kilteni, R. Groten and M. Slater, "The sense of embodiment in virtual reality," *Presence: Teleoperators and Virtual Environments*, vol. 21, no. 4, pp. 373–387, Aug. 2012, doi: 10.1162/PRES_a_00124.
- [22] D. R. Garrison, T. Anderson, and W. Archer, "Critical inquiry in a text-based environment: Computer conferencing in higher education," *Internet Higher Educ.*, vol. 2, no. 2–3, pp. 87–105, 2000.
- [23] C. N. Gunawardena and F. J. Zittle, "Social presence as a predictor of satisfaction within a computer-mediated conferencing environment," *Amer. J. Distance Educ.*, vol. 11, no. 3, pp. 8–26, 1997. <https://doi.org/10.1080/08923649709526970>.

- [24] F. Biocca, C. Harms, and J. K. Burgoon, "Toward a more robust theory and measure of social presence: Review and suggested criteria," *Presence Teleoper. Virtual Environ.*, vol. 12, no. 5, pp. 456–480, 2003. <https://doi.org/10.1162/105474603322761270>
- [25] M. Botvinick and J. Cohen, "Rubber hands 'feel' touch that eyes see," *Nature*, vol. 391, p. 756, 1998. <https://doi.org/10.1038/35784>
- [26] M. Slater, B. Spanlang, and D. Corominas, "Simulating virtual environments within virtual environments as the basis for a psychophysics of presence," *ACM Trans. Graph.*, vol. 29, no. 4, pp. 1–9, 2010.
- [27] N. Yee and J. Bailenson, "The Proteus effect: The effect of transformed self-representation on behavior," *Human Communication Research*, vol. 33, no. 3, pp. 271–290, Jul. 2007. doi: 10.1111/j.1468-2958.2007.00299.x.
- [28] N. Yee, J. N. Bailenson, and N. Ducheneaut, "The Proteus effect: Implications of transformed digital self-representation on online and offline behavior," *Communication Research*, vol. 36, no. 2, pp. 285–312, Apr. 2009. doi: 10.1177/0093650208330254.
- [29] M. C. Johnson-Glenberg, "Immersive VR and education: Embodied design principles that include gesture and hand controls," *Front. Robot. AI*, vol. 5, p. 81, 2018. <https://doi.org/10.3389/frobt.2018.00081>
- [30] R. Ratan, M. S. Klein, C. R. Ucha, and L. L. Cherchiglia, "Avatar customization orientation and undergraduate-course outcomes: Actual-self avatars are better than ideal-self and future-self avatars," *Comput. Educ.*, vol. 191, p. 104643, 2022.
- [31] R. Ratan and Y. J. Sah, "Leveling up on stereotype threat: The role of avatar customization and avatar embodiment," *Comput. Hum. Behav.*, vol. 53, pp. 299–305, Dec. 2015. [Online]. Available:<https://doi.org/10.1016/j.chb.2015.07.020>